

**RISK ANALYSIS OF FORMALDEHYDE EMISSIONS IN MORTUARIES CASE
STUDY OF FIVE MORTUARIES INSIDE A FACULTY OF MEDICINE IN EGYPT**

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ABSTRACT

Formaldehyde is a volatile organic compound that has serious effects on human health and considered a human carcinogen based on sufficient human and animal inhalation studies. In mortuaries, formaldehyde is commonly used for the preservation of the dead. Formaldehyde was measured during working hours in March 2018 in five mortuaries in Egypt. Formaldehyde recorded 1.69 ± 0.72 , 1.80 ± 0.69 , 0.94 ± 0.56 , 1.08 ± 0.33 , and 0.13 ± 0.05 ppm in the five mortuaries. These concentrations exceeded air quality limits of the Egyptian Environmental Affairs Agency (0.3ppm) in all sites except the 5th mortuary and exceeded air quality limits of the National Institute for Occupational Safety and Health in all sites (0.016. ppm). Hazard Rating Number system is used in this work as a simple tool to assess the risk of exposure to formaldehyde in mortuaries and recorded high levels of risk in most cases. The study indicated that Hazard Rating Number system can be used as a preliminary risk assessment tool that can be calculated by non-specialists to take decisions when high formaldehyde concentration is detected. According to the risk control hierarchy, there are several control options that need further scientific studies such as using virtual reality and augmented reality, decreasing noise of ventilation systems, and substitution of formaldehyde by other preservative solutions to decrease the risk of exposure to formaldehyde in mortuaries. Finally, the study focused on the serious need for risk communication activities to increase awareness of workers and students about formaldehyde health risk.

Keywords: Formaldehyde; Hazard rating number system; Indoor Air Pollution; Risk assessment; Ventilation.

1. INTRODUCTION

Formaldehyde (FA) is a volatile organic compound (VOC) with the formula CH_2O . It is the simplest form of aldehydes (Alessandro *et al.*, 2019). FA is a colorless, flammable gas that has a distinct, pungent smell at room temperature. Small amounts of FA are naturally produced by plants, animals, and humans. FA has serious effects on human health. Nasal and eye irritation, neurological effects, and increased risk of asthma and/or allergy have been observed at 0.1 and 0.5 ppm. Eczema and changes in lung function have been observed at 0.6 to 1.9 ppm. Decreased body weight, gastrointestinal ulcers, liver and kidney damage were observed in animals orally exposed to 50-100 milligrams/kilogram/day (mg/kg/day) FA. The International Agency for Research on Cancer (IARC) has classified formaldehyde as carcinogenic to humans (Group 1) as

there is sufficient evidence in humans and experimental animals for the carcinogenicity of formaldehyde (IARC, 2012). Also, the United States Department of Health and Human Services (HHS) determined in 2011 that FA is a known human carcinogen based on sufficient human and animal inhalation studies by Agency for Toxic Substances and Disease Registry (ATSDR, 2015). Work-related contact with FA happens in a multiplicity of diverse areas, although employees at greater risk are those engaged in the healthcare areas (specially mortuaries) and in wood treating manufacturing (Alessandro *et al.*, 2019; Scarselli *et al.*, 2017). The hospital environment is complex and presents a large number of risks for its workers. Generally, in a hospital, there is exposure to nonspecific risk factors (such as falling off a ladder or slippery pavement) that may arise in any other work environment and more specific risk factors (bites, cuts or perforations with potentially infected sharps), relevant biological agents, chemical exposure, ionizing and non-ionizing radiation, mechanical factors, as well as ergonomic issues such as the continued manual movement of dependent patients. The risk of a healthcare professional contracting work-related illness is about 1.5 times greater than the risk of all other workers. In mortuaries, FA is commonly used for the preservation (embalment) of the dead. Mortuary workers and medical students are exposed daily to FA by inhalation and skin contact (Sousa *et al.*, 2017; Obed-Whyte *et al.*, 2019). The term risk analysis is used by World Health Organization (WHO) and Food and Agriculture Organization (FAO) to encompass all components of risk; risk assessment, risk management, and risk communication (Fig. 1) (Nauta *et al.*, 2018). Office of the Gene Technology Regulator (OGTR) defined risk assessment as a science-based component that identifies risks from plausible sets of circumstances that may result in harm to people or to the environment and estimating the level of risk on the basis of the seriousness and chance of harm, while risk management is identified as a Policy-based component that evaluates, selects, and implements plans or actions to ensure risks are appropriately managed (OGTR, 2009). According to National Institute for Occupational Safety and Health (NIOSH), risks can be managed as shown in Fig. 2 by removing the hazard, replacing the hazard, isolating people from the hazard, changing the way people work, and/or protecting workers with personal protective equipment (PPEs) respectively (NIOSH, 2015). Risk communication is the exchange of information, ideas, and views between the regulator and stakeholders; it also conveys the rationale for decisions made by the regulator (OGTR, 2009).

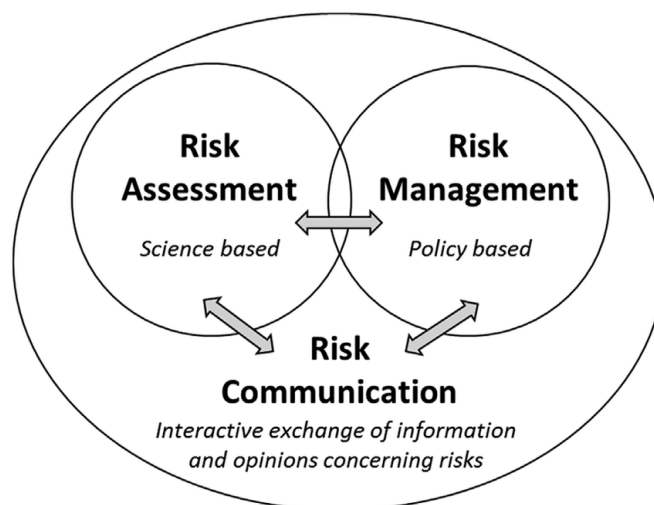
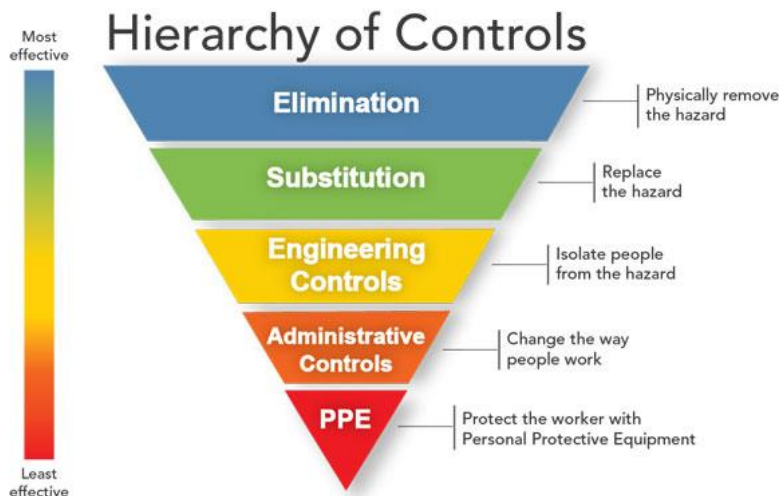


Fig. 1: The risk analysis framework with the elements risk assessment,**Risk management and risk communication (Nauta *et al.*, 2018)****Fig. 2: Hierarchy of Controls (NIOSH, 2015)**

This study aims to compare FA concentrations in the working environment of five mortuaries in Egypt with exposure limits of national authorities, international organizations, and the results of other studies. Also, this study aims to assess the risk of exposure to FA in these mortuaries and explore the different options to control this risk. This study has been carried out in five mortuaries inside a faculty of medicine in Egypt in 2018.

2. MATERIALS AND METHODS

FA measurements

FA was measured during working hours in five mortuaries in Egypt using First Check which is an intrinsically safe portable gas detector, designed for the detection of numerous gases such as (TVOC's, FA, Xylene, Butanol, ...etc.) and others hydrocarbon fuels, solvents, semi-conductor gases using photoionization detector (PID). A small internal pump draws gas through the Photo Check probe and through a PID cell. Ultraviolet (UV) light from the photic lamp penetrates and converts some of the gas within the PID cell into positive and negative ions. These are then separated electrically within the cell into a detectable current, which is particularly large for hydrocarbon gases present. The photo-ionization current is amplified and scaled for display as a concentration, either ppb or ppm or mg/m³ units for a specific target gas and photic lamp combination (Ion science, 2009).



Fig. 3: Used instrument for FA measurements (First Chick)

Air quality limits (AQLs)

Results of FA measurements were compared to AQLs which approved by National Institute for Occupational Safety and Health (NIOSH), Occupational Safety and Health Administration (OSHA), and Egyptian Environmental Affairs Agency (EEAA). [Table 1](#) shown Short Term Exposure Limits (STEL), Time-weighted Average (TWA), and Ceiling borders for FA in part per millions (ppm). NIOSH considers formaldehyde to be a potential occupational carcinogen and hence adopted lower limits ([NIOSH,2007](#); [EEAA, 2011](#)).

Table 1: AQLs of FA according to exposure time

Pollutant	OSHA		NIOSH		EEAA
	STEL	TWA8	15 min. (Ceiling)	TWA8	Ceiling border
Formaldehyde(ppm)	2	0.75	0.1	0.016	0.3

Ventilation in mortuaries

Ventilation rates in these five mortuaries were calculated from the suction system capacity in each mortuary and compared to EEAA acceptable limits as shown in [Table 2](#)([EEAA, 2011](#)). Mortuaries were not included in the law and hence were considered as a science lab because of the presence of practical sections for students of medical faculty.

Table 2: Minimum required ventilation rate for public and closed places

Table 2: Minimum required ventilation rate for public and closed places			
No.	Place/ Activity	Occupancy density (person/100 m ²)	Minimum Ventilation Rate (liter/second/person)
Education places:			
1	- Small lecture room	65	4.3
	- Lecture hall		
	- Science lab	150	4.2
Restaurants and cafeterias:			
2	- Restaurants (eating rooms)	50	10
	- Cafeteria / fast food places		
Hotels and Resorts :			
3	- Bedrooms / living	10	8.4
	- Entrance foyer / saloons		
Administrative Buildings:			
4	- Office room	5	10
	- Reception area / main entrance foyer	30	5.5
	- Meetings Hall		
	- Conferences Hall	50	8
Gatherings places:			
5	- Concert halls Cinema Theater	10	8
	- Public libraries		
	- Museums	10	8.5
	- Exhibitions		
Fun /sports places:			
6	- Indoor games halls (onlookers)	100	8
	- Health Club (Aerobics)		
	- Gymnasiums	40	8
Notes: - The above limits are acceptable if smoking is prohibited in these places.			
- Occupancy density is used when the actual occupancy density not available.			

Risk assessment

There are numerous ways of assessing the risk involved with a hazard. The Hazard Rating Number system (HRN) used in this work as a simple tool for risk assessment of exposure to FA in five mortuaries in Egypt. A key to the number system is detailed in [Tables 3](#). HRN can be calculated according to eq. 1. $H.R.N. = LO * FE * DPH * NP$ (1)

Where LO is the likelihood of occurrence, FE is the frequency of exposure, DPH is the degree of possible harm, and NP is the number of persons at risk ([TÜV SÜD Product Service, 2015](#)).

Table 3: Hazard rating number system (HRN)

	Likelihood	LO	Frequency	FE
Impossible	cannot happen	0	Infrequently	0.1
Almost unlikely	possible in extreme circumstances	0.1	Annually	0.2
Highly unlikely	though conceivable	0.5	Monthly	1
Unlikely	but could occur	1	Weekly	1.5
Possible	but unusual	2	Daily	2.5
Even chance	could happen	5	Hourly	4
Probable	not surprised	8	constantly	5
Likely	to be expected	10		
Certain	no doubt	15		
Possible Harm		DPH	No. of Persons	NP
Scratch or bruise		0.1	1-2 persons	1
Laceration or mild ill health		0.5	3-7 persons	2
Break of a minor bone or minor illness (temporary)		1	8-15 persons	4
Break of a major bone or minor illness (permanent)		2	16-50 persons	8
Loss of Limb/ eye/ serious illness of a temporary nature		4	50 + persons	12
Loss of Limbs/ eyes/ serious illness of permanent nature		8		
Fatality		15		

RISK	Negligible	Very Low	Low	Significant	High	Very High	Extreme	Unacceptable
HRN	0-1	1-5	5-10	10-50	50-100	100-500	500-1000	Over 1000

Table 4: Appropriate time for corrective actions (SHP, 2015)

HRN	RISK	Action time table
0-1	Negligible	Accept Risk
1-5	Very Low	Action within 1 year
5-10	Low	Action within 3 months
10-50	Significant	Action within 1 month
50-100	High	Action within 1 week
100-500	Very High	Action within 1 day
500-1000	Extreme	Immediate Action
Over 1000	Unacceptable	Stop the activity

DPH was modified by the author according to expected health impacts related to FA concentrations and TWA₈ limits of several organizations and developed countries as shown in [Table 5](#).

Table 5: DPH for FA inhalable concentrations

TWA ₈ limits	Suggested FA range (by author)	Possible health harm	DPH
	< 0.016 ppm		0.1
NIOSH (0.016 ppm) (NIOSH, 2007)	0.016 - 0.1 ppm		0.5
	0.1 - 0.3 ppm	Nasal and eye irritation, neurological effects, and increased risk of asthma and/or allergy have been observed in humans breathing 0.1 to 0.5 ppm (ATSDR, 2015).	1
Finland and Germany (0.3 ppm) (Kim et al., 2011)	0.3 - 0.5 ppm		2
Japan (0.5 ppm) (Kim et al., 2011)	0.5 - 0.75 ppm	Eczema and changes in lung function have been observed at 0.6 to 1.9 ppm (ATSDR, 2015).	4
OSHA (0.75 ppm) (NIOSH, 2007)	0.75 - 1 ppm		8
Australia (1 ppm) (Kim et al., 2011)	> 1 ppm	It is likely that low levels (<1 ppm) of formaldehyde can have only a minimal (or non-existent) carcinogenic potential on human cancer risk (Kim et al., 2011).	15

4. RESULTS AND DISCUSSION

Formaldehyde concentrations

Formaldehyde has been measured during working hours in March 2018 in 5 mortuaries as shown in Table 6. Suction fans didn't work in mortuaries (1 to 4) during measurements (this is the default status in them), while in the mortuary (5), it was working well. FA measurements in the mortuary (1) were repeated to test the suction efficiency. Also, FA was measured near the dead bodies' basin as it represents a major source for FA. Finally, FA was measured outside mortuaries. Results indicated that mean FA concentrations exceeded AQLs (Ceiling) of EEAA in all sites except mortuary (5). According to OSHA, 5 sites exceeded AQLs (TWA₈) while, 3 sites (Mortuary (1) "suction fans ON", Mortuary (5), and outside mortuaries) recorded concentrations within AQLs. According to NIOSH, all sites exceeded AQLs (TWA₈). The area near the dead bodies' basin recorded the highest FA concentration (2.21 ppm) which represents about 6 folds of AQLs (Ceiling) of EEAA.

Table 6: Range, mean, and standard deviation of FA concentrations at various sites inside the working environment of medicine faculty mortuaries, Egypt (March 2018)

Code	Site Description	n (*)	Max. (ppm)	Min. (ppm)	Mean ± SD (ppm)	OSHA (TWA ₈)	NIOSH (TWA ₈)	EEAA (Ceiling)
01	Mortuary (1) (suction fans OFF)	56	3.40	0.62	1.69 ± 0.72			
02	Mortuary (2) (suction fans OFF)	65	2.96	0.39	1.80 ± 0.69			
03	Mortuary (3) (suction fans OFF)	67	2.36	0.02	0.94 ± 0.56			
04	Mortuary (4) (suction fans OFF)	27	1.70	0.43	1.08 ± 0.33	0.75	0.016	0.37
						ppm	ppm	ppm
05	Mortuary (5) (suction fans ON)	14	0.22	0.08	0.13 ± 0.05			
06	Mortuary (1) (suction fans ON)	19	0.99	0.16	0.49 ± 0.30			
07	Near the dead bodies' basin	35	2.64	1.85	2.21 ± 0.20			
08	Outside mortuaries (corridor)	7	0.56	0.49	0.53 ± 0.02			
(*)n:total no. of samples								

There are few Published papers that measured FA in mortuaries. [Suruda et al. \(1993\)](#) recorded that the average FA air concentration during embalming courses in Cincinnati College of Mortuary Science (CCMS) was 1.4 ppm with a range of 0.15 – 4.3 ppm. Also, [Roland et al. \(2019\)](#) found that the mean TWA₈ concentration of formaldehyde in public and private mortuaries was 2.42±1.77 and 2.52±0.99 ppm respectively. On the other hand, a distinct study in Netherlands indicated that FA concentrations in mortuaries can be reduced significantly. Over a period of 6 years mitigating measures were introduced, including technical improvement and organizational changes. Geometric mean (GM) concentrations of FA in the breathing zone over a work-shift were 123 µg/m³(0.0985 ppm)in 2012 and 114 µg/m³(0.0913 ppm) in 2014. This exposure was reduced to an average of 28.8 µg/m³(0.023 ppm) in 2017 [Scheepers et al. \(2018\)](#).

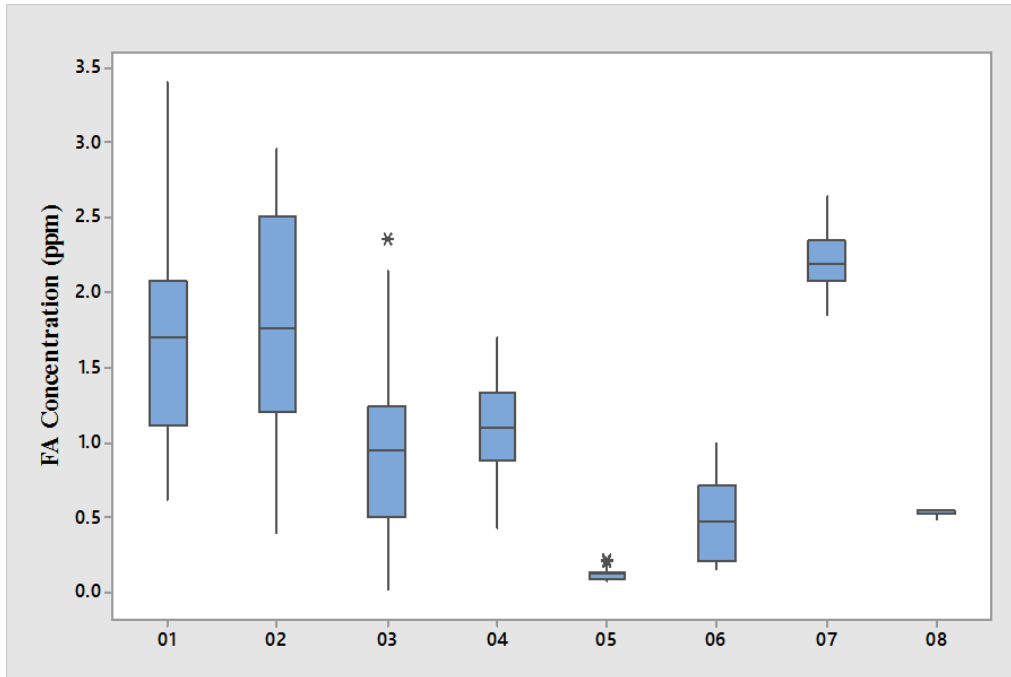


Fig. 4: Boxplot of measured FA concentrations (ppm) in the mortuaries

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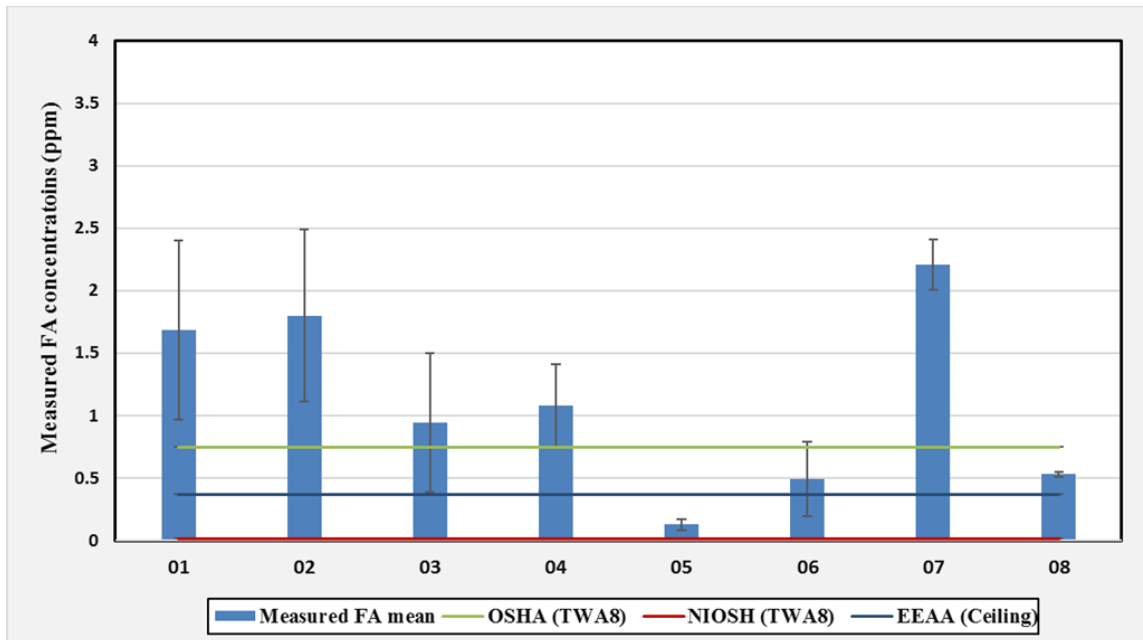


Fig. 5: Comparing FA mean concentrations (ppm) in the mortuaries to AQLs

Measurements of Ventilation Rates

The full capacity of air regeneration by the suction fans in the five mortuaries was calculated and compared to EEA minimum acceptable regeneration rate as shown in Tables 7 and 8. The mortuaries were considered as a science laboratory.

- Minimum acceptable regeneration rate = 8.6 l/s/person
- Occupancy density = 25 person/100 m² (If actual occupancy density is higher than 25 person/100 m², the greater value is used in calculating the air regeneration rate).

Results of calculations indicated that the full capacity air regeneration rates by suction fans (m³/s) inside the mortuaries were (theoretically) higher than the minimum EEA acceptable regeneration rate. But actually, except the 5th mortuary, the capacity of suction fans decreased to 15% (as a maximum) from its full capacity. Also, medical students usually asked mortuary workers to stop them during practical sections because of its noise and then FA recorded high concentrations as shown above in these mortuaries.

Table 7: Shown EEA minimum acceptable regeneration rate in the five mortuaries

Mortuary No.	Mortuaries dimensions			Area (m ²)	Volume (m ³)	No. of people (*)	Occupancy density (**) (person / 100 m ²)	Minimum acceptable ventilation rate (***) (m ³ /s)
	Length (m)	Width (m)	Height (m)					
M. 1	12.6	10.7	2.9	134.8	391.0	~ 100	74	0.86
M. 2	15.0	12.5	2.9	187.5	543.8	~ 100	53	0.86
M. 3	12.1	10.6	2.9	128.3	372.0	~ 100	78	0.86
M. 4	12.0	4.0	2.9	48.0	139.2	~ 80	167	0.688
M. 5	6.1	6.0	2.9	36.6	106.1	~ 45	122	0.387

(*) No. of people: the total no. of peoples inside mortuaries including workers, medical students, and teaching assistants

(**) Occupancy density (person / 100 m²) = (Total no. of peoples * 100) / Area (m²)

(***) Minimum acceptable ventilation rate (m³/s) = Total no. of peoples * 8.6*10⁻³

Table 8: shown calculations of air regeneration by the suction systems (full capacity)

Mortuary No.	Suction fan (Type :1) (Capacity = 3400 m ³ /h)		Suction fan (Type :2) (Capacity = 1800 m ³ /h)		Regeneration rate by suction (1) + (2) (m ³ /h)	Regeneration rate by suction (1) + (2) (m ³ /s)
	No.	Total (m ³ /h)	No.	Total (m ³ /h)		
	M. 1	4	13600	0	--	13600
M. 2	5	17000	3	5400	22400	6.22
M. 3	4	13600	0	--	13600	3.78
M. 4	2	6800	0	--	6800	1.89
M. 5	2	6800	0	--	6800	1.89

Risk assessment

In addition to measured FA concentrations, other data about working periods in mortuaries were collected as shown in Table 9. HRNs were calculated using Eq. 1 for the five mortuaries as shown in Tables 10, 11, and 12. Calculated HRN was corresponded to unacceptable risk for workers, teaching assistants, and students in M.1, M.2, and M.4. HRN for M.3 was lower than them because FA concentration was slightly lower than them. The lowest calculated HRN noticed in M.5 (corresponded to the lowest FA concentration).

Table 9: Data of exposed persons to FA in mortuaries

Exposed people		M. 1	M. 2	M. 3	M. 4	M. 5
Mortuaries Workers	Total number	3	3	3	3	3
	Working days per week	5	5	5	5	5
	Working hours per day	9	9	9	9	9
Teaching assistants	Total number	4	4	4	4	4
	Working days (in mortuaries) per week	4	4	4	4	4
	Working hours (in mortuaries) per day	2	2	2	2	2
Medical Students	Total number of sections in each mortuary per week	24	24	24	24	24
	Total number of students per section	~ 100	~ 100	~ 100	~ 80	~ 45
	Duration of each section (hrs.)	2	2	2	2	2
	No. of sections for each student per week	4	4	4	4	4

Table 10: Calculations of HRN and corresponding risk and action time for mortuaries workers

Mortuary No.	LO	FE	DPH	NP	HRN	RISK	Action Time
M. 1	15	4	15	2	1800	Unacceptable	Stop the activity
M. 2	15	4	15	2	1800	Unacceptable	Stop the activity
M. 3	15	4	8	2	960	Extreme	Immediate Action
M. 4	15	4	15	2	1800	Unacceptable	Stop the activity
M. 5	15	4	1	2	120	Very High	Action within 1 week

Table 11: Calculations of HRN and corresponding risk and action time for teaching assistants

Mortuary No.	LO	FE	DPH	NP	HRN	RISK	Action Time
M. 1	15	2.5	15	2	1125	Unacceptable	Immediate Action
M. 2	15	2.5	15	2	1125	Unacceptable	Immediate Action
M. 3	15	2.5	8	2	600	Extreme	Action within 1 day
M. 4	15	2.5	15	2	1125	Unacceptable	Immediate Action
M. 5	15	2.5	1	2	75	High	Action within 1 month

Table 12: Calculations of HRN and corresponding risk and action time for medical students

Mortuary No.	LO	FE	DPH	NP	HRN	RISK	Action Time
M. 1	15	1.5	15	12	4050	Unacceptable	Stop the activity
M. 2	15	1.5	15	12	4050	Unacceptable	Stop the activity
M. 3	15	1.5	8	12	2160	Unacceptable	Immediate Action
M. 4	15	1.5	15	12	4050	Unacceptable	Stop the activity
M. 5	15	1.5	1	12	270	Very High	Action within 1 week

Risk Management

Exposure to high concentrations of FA is a major problem in mortuaries, especially in developing countries, and need a lot of precautions to protect workers, medical students, and teaching assistants from the serious health risks caused by FA. In this work, several precautions are suggested to decrease this risk as shown in [Table 14](#).

Table 13: Risk control options for FA emissions in mortuaries

Risk control level	Available precautions
Elimination	<ol style="list-style-type: none"> <li data-bbox="402 373 1471 562">1. The risk of exposure to FA emissions in mortuaries can be eliminated by using virtual reality (VR) and augmented reality (AR) as effective and capable resources for anatomy teaching in terms of both academic achievement and student satisfaction (Heather <i>et al.</i>, 2019). But VR and AR can't eliminate this risk completely as Saltarelli <i>et al.</i> (2014) found that the human cadaver laboratory offered a significant advantage over the multimedia simulation program on cadaver-based measures of identification and explanatory knowledge. <li data-bbox="402 569 1471 663">2. Also, this risk can be eliminated by using human-tissue-mimicking materials such as natural rubber nanocomposite, silicon, and Polyvinyl Chloride (PVC) instead of human cadavers (Murniatia <i>et al.</i>, 2017; Wanget <i>et al.</i>, 2014; Li <i>et al.</i>, 2015).
Substitution	<ol style="list-style-type: none"> <li data-bbox="402 672 1471 861">3. Phenoxyethanol is suggested to be a substitute for formaldehyde in preservation of dead bodies (Frølich <i>et al.</i>, 1984). Also, Ethyl alcohol and polyethylene glycol (Kryofix) and Glutaraldehyde are suggested as potential alternatives (Mao <i>et al.</i>, 1994). There are several substances used in modern anatomical embalming instead of FA but none is the subject of consensus (Goyeret <i>et al.</i>, 2006; Brenneret <i>et al.</i>, 2014). Kumar <i>et al.</i> (2014) reported that "it is impractical to find out non-toxic embalming solution" <li data-bbox="402 867 1471 909">4. Substitution with lower concentration of formaldehyde solution (Elsaer <i>et al.</i>, 2017).
Engineering Control	<ol style="list-style-type: none"> <li data-bbox="402 917 1471 1113">5. Well ventilation in mortuaries decreases FA concentrations and hence decreases its risk, but it is generally recognized the operation of ventilation systems is one of the noisy activities which causes students to be distracted (Students usually asked the mortuary' workers to stop the ventilation system!). This problem can be solved by adding inertia blocks to increase the stability of the ventilation system, providing flexible connectors between the fan and associated ducts, using sound-absorbing materials ... etc. (EPD, 2006). <li data-bbox="402 1119 1471 1255">6. Leak prevention: by closing every probable source of FA emissions such as pools in which the dead parts are collected after practical sections (in this study, FA concentrations near them were very high). The cover would only have to be opened for introduction or removal of specimens (Scheepers <i>et al.</i>, 2018).
Administrative controls	<ol style="list-style-type: none"> <li data-bbox="402 1264 1471 1381">7. Instead of collecting the leak drained fluid in an absorbent disposable tissue and an open bucket to collect any formalin dripping from the tables, (allowing the FA to evaporate from this secondary source) the drained liquid would be removed and collected in a closed containment (Scheepers <i>et al.</i>, 2018). <li data-bbox="402 1388 1471 1478">8. Optimizing storage system by storage of specimens needed for a specific class/course in one or a few labelled tanks to reduce on the number of tanks to be opened to retrieve the required specimens (Scheepers <i>et al.</i>, 2018). <li data-bbox="402 1484 1471 1541">9. Workers should get out of the morgue periodically to breathe clean air outside and not be in the morgue unnecessarily. <li data-bbox="402 1547 1471 1612">10. Imposing sanctions on any worker or a student entering the morgue without wearing respirators
PPEs	<ol style="list-style-type: none"> <li data-bbox="402 1621 1471 1709">11. Workers, Students, and teaching assistants must wear suitable masks, eyeglasses, and gloves during sections.

Risk communications

All risk control precautions will be useless without increase awareness of people at risk and administrative board. In this study, suction fans can decrease FA concentrations but workers and students choose to stop them and don't care about the risk of FA accumulation in the mortuaries. Awareness lectures, posters, and workshops must be conducted periodically for workers and students.

5. CONCLUSION

FA recorded concentrations higher than AQLs of EEAA (Ceiling), OSHA (TWA₈), and NIOSH (TWA₈) in four mortuaries. M.05 only recorded concentration lower than AQLs of EEAA (Ceiling) and OSHA (TWA₈) but still higher than NIOSH (TWA₈). The highest FA concentration was recorded near the dead bodies' basin.

Ventilation system capacity was calculated and air regeneration rates inside all mortuaries were (theoretically) higher than the minimum EEAA acceptable regeneration rate. But actually, except the 5th mortuary, the capacity of suction fans decreased to 15% (as a maximum) from its full capacity. Also, medical students usually asked mortuaries workers to stop them during practical sections because of its noise.

Calculated HRN corresponded to unacceptable risk for workers, medical students, and teaching assistants in M.1, M.2, and M.4. HRN of M.3 was lower than them for workers and teaching assistants but still in the level of extreme risk for workers and for students. The lowest calculated HRN noticed in M.5 and its risk considered high for workers and for students. These results indicated that working and education sessions in mortuaries are risky and need several precautions.

According to risk control hierarchy, several precautions were suggested to control FA risk such as using of virtual reality (VR) and augmented reality (AR) for anatomy teaching, using of human-tissue-mimicking materials instead of human cadavers, substitution of FA with other preservative solutions that have less toxicity, use of less concentrated formaldehyde solutions, well ventilation with noise decreasing measures, good closing of pools of preservation, administrative controls, and wearing suitable PPEs usually inside mortuaries. Finally, the study indicated that;

1. HRN system can be used as a preliminary risk assessment tool that can be calculated by non-specialists to take decisions when high FA concentration is detected.
2. Risk communication activities are needed to increase awareness of workers and students about FA health risks.
3. There are several control options that need further scientific studies such as using of VR and AR in anatomy sessions, decreasing noise of ventilation systems, and substitution of formaldehyde by other preservative solutions.

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CONFLICT OF INTEREST

The author declares that there is no conflict of interests regarding the publication of this manuscript. In addition, the ethical issues, including plagiarism, informed consent, misconduct, data fabrication and/or falsification, double publication and/or submission, and redundancy have been completely observed by the authors.

ABBREVIATIONS

<i>AQL</i>	AirQuality Limit
<i>ATSDR</i>	Agency for Toxic Substances and Disease Registry
<i>AR</i>	Augmented Reality
<i>CCMS</i>	Cincinnati College of Mortuary Science
<i>DPH</i>	Degree of Possible Harm
<i>EEAA</i>	Egyptian Environmental Affairs Agency
<i>EPD</i>	Environmental Protection Department
<i>FA</i>	Formaldehyde
<i>FAO</i>	Food and Agriculture Organization
<i>FE</i>	Frequency of Exposure
<i>GM</i>	Geometric mean
<i>HHS</i>	Health and Human Services
<i>HRN</i>	Hazard Rating Number
<i>IARC</i>	International Agency for Research on Cancer
<i>LO</i>	Likelihood of Occurrence
<i>l/s/person</i>	liter/second/person
<i>m²</i>	Square meters
<i>m³/h</i>	Cubic meters per hour
<i>m³/s</i>	Cubic meters per second
<i>n</i>	total number of samples
<i>NIOSH</i>	National Institute for Occupational Safety and Health
<i>NP</i>	Number of Persons at risk
<i>OGTR</i>	Office of the Gene Technology Regulator
<i>OSHA</i>	Occupational Safety and Health Administration
<i>PEL</i>	Permissible Exposure Limit
<i>PID</i>	Photoionization detector
<i>PPE</i>	Personal Protective Equipment
<i>ppm</i>	part per million
<i>SD</i>	Standard Deviation
<i>SHP</i>	Safety and Health Practitioner
<i>STEL</i>	Short Time Exposure Limit
<i>TWA₈</i>	Time-weighted Average (8 hours)
<i>UV</i>	Ultra Violet
<i>µg/m³</i>	microgram per cubic meter
<i>VOCs</i>	Volatile Organic Compounds
<i>VR</i>	Virtual Reality
<i>WHO</i>	World Health Organization

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